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# Design and fabrication of axial flux ferrite magnet brushless DC motor for electric two-wheelers

**M. Fasil[a], N. Mijatovic[a], J. Holbøll[a], B.B. Jensen[b], J. Almunia[c], A. Seoane[c], and R. Altimira[c]**

*[a]Department of Electrical Engineering, Technical University of Denmark, Kgs. Lyngby, 2800, Denmark. Tel: (+45) 45 25 35 00;*

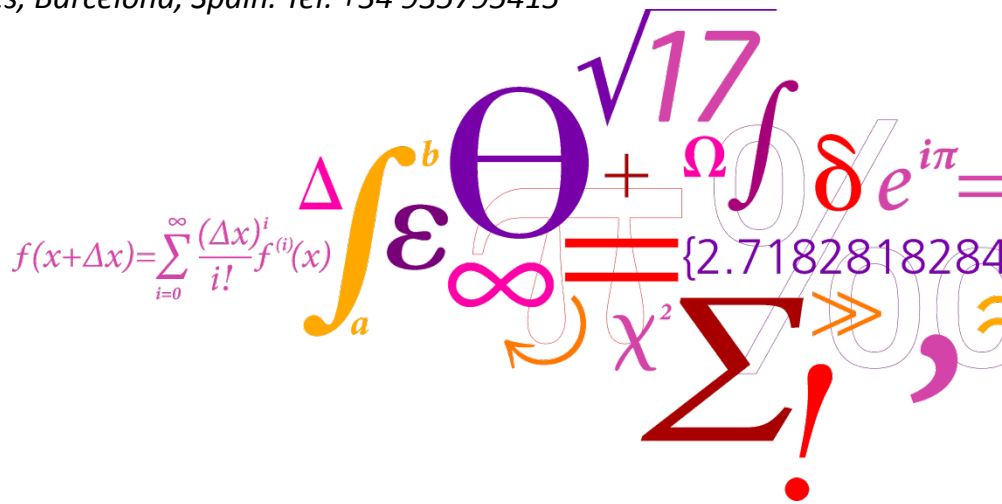
*[b]Department of Science and Technology, University of the Faroe Islands, Torshavn, FO-100, Faroe Islands. Tel: +298 292560*

*[c]IMA S.L., Avda. Rafael Casanova 114, 08100 Mollet del Vallés, Barcelona, Spain. Tel: +34 935795415*

*Presented by*

Muhammed Fasil

Ph.D. Student



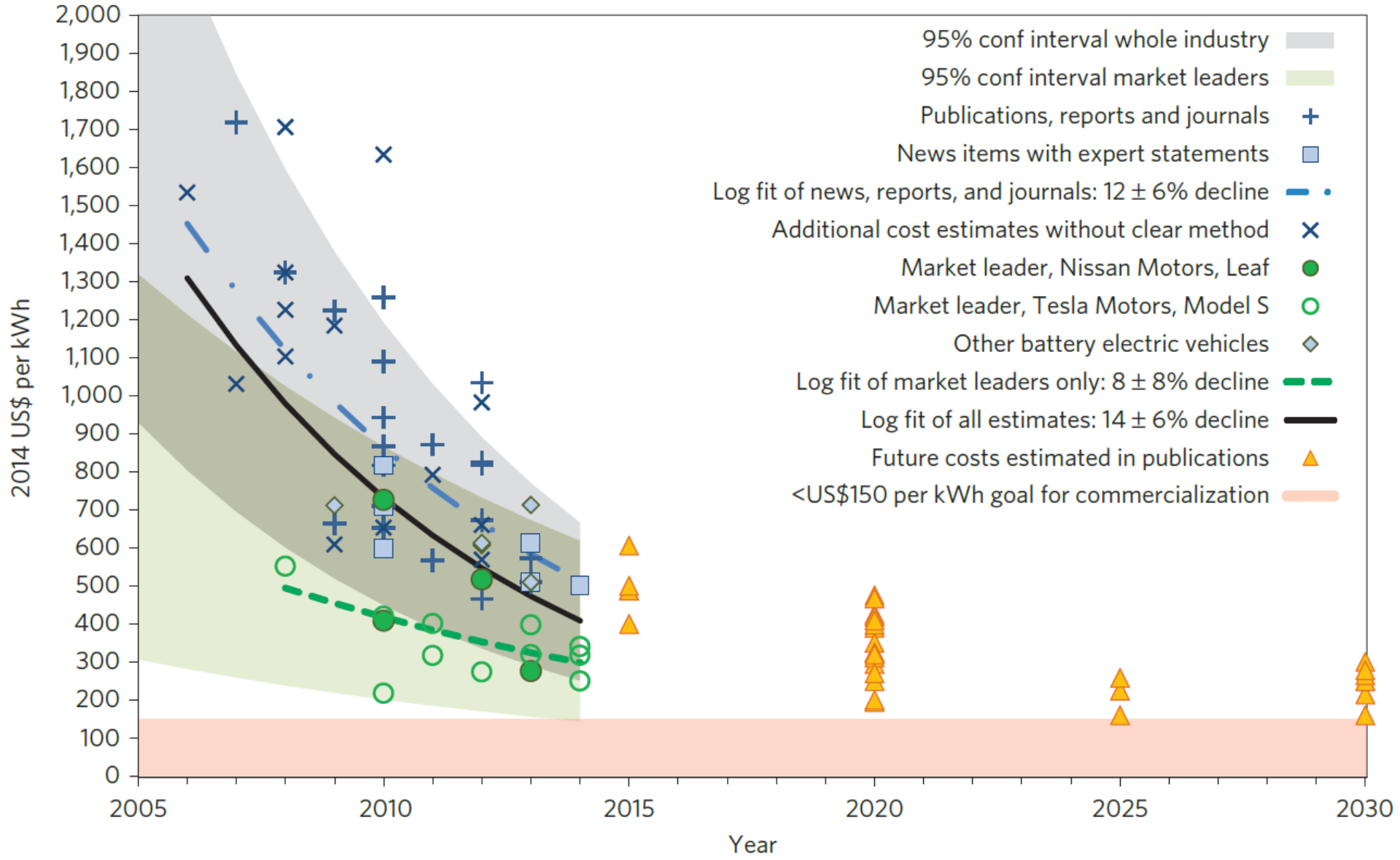

DTU Electrical Engineering

Department of Electrical Engineering

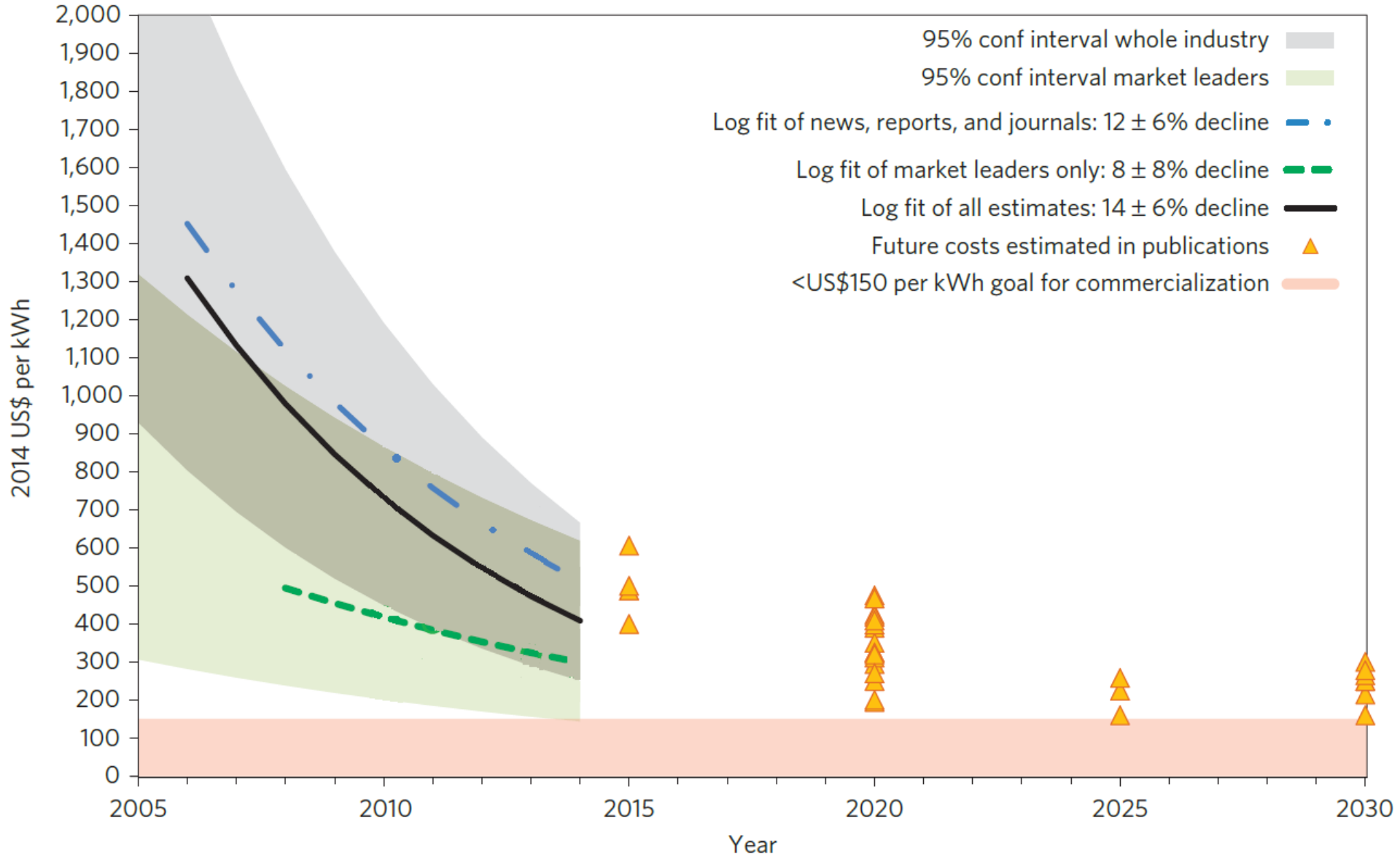
# Background - Importance of improved ferrite magnets to the growth of electric vehicle

- There is a demand for electric vehicle (EV) propelled by environmental causes and fuel price fluctuations

- At present, performance/price factor compared to IC engine vehicles are holding back the growth of EVs




[1] B. Nykvist and M. Nilsson, “Rapidly falling costs of battery packs for electric vehicles,” Nat. Clim. Chang., vol. 5, no. 4, pp. 329–332, Mar. 2015.

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# Background - Importance of improved ferrite magnets to the growth of electric vehicle

- There is a demand for electric vehicle (EV) propelled by environmental causes and fuel price fluctuations
- At present, performance/price factor compared to IC engine vehicle are holding back the growth of EV
- The cost of batteries used in electric vehicles (EVs) has been falling fast and is almost certainly well below the estimates made by many analysts in the past decade[1].
- A low cost powertrain could lead to affordable, efficient and performing EVs in market earlier than expected!
- Introduction of improved energy density ferrite magnet based PM motors is a possible solution to low-cost powertrain

[1] B. Nykvist and M. Nilsson, "Rapidly falling costs of battery packs for electric vehicles," Nat. Clim. Chang., vol. 5, no. 4, pp. 329–332, Mar. 2015.

# Outline

- Background
- Specification of electric motor powertrain for two-wheeler
- Challenges in substituting rare earth magnet with ferrite in electrical machines
- Design details of ferrite magnet motor
- Mechanical assembly of motor
- Fabrication of the motor
- Conclusion

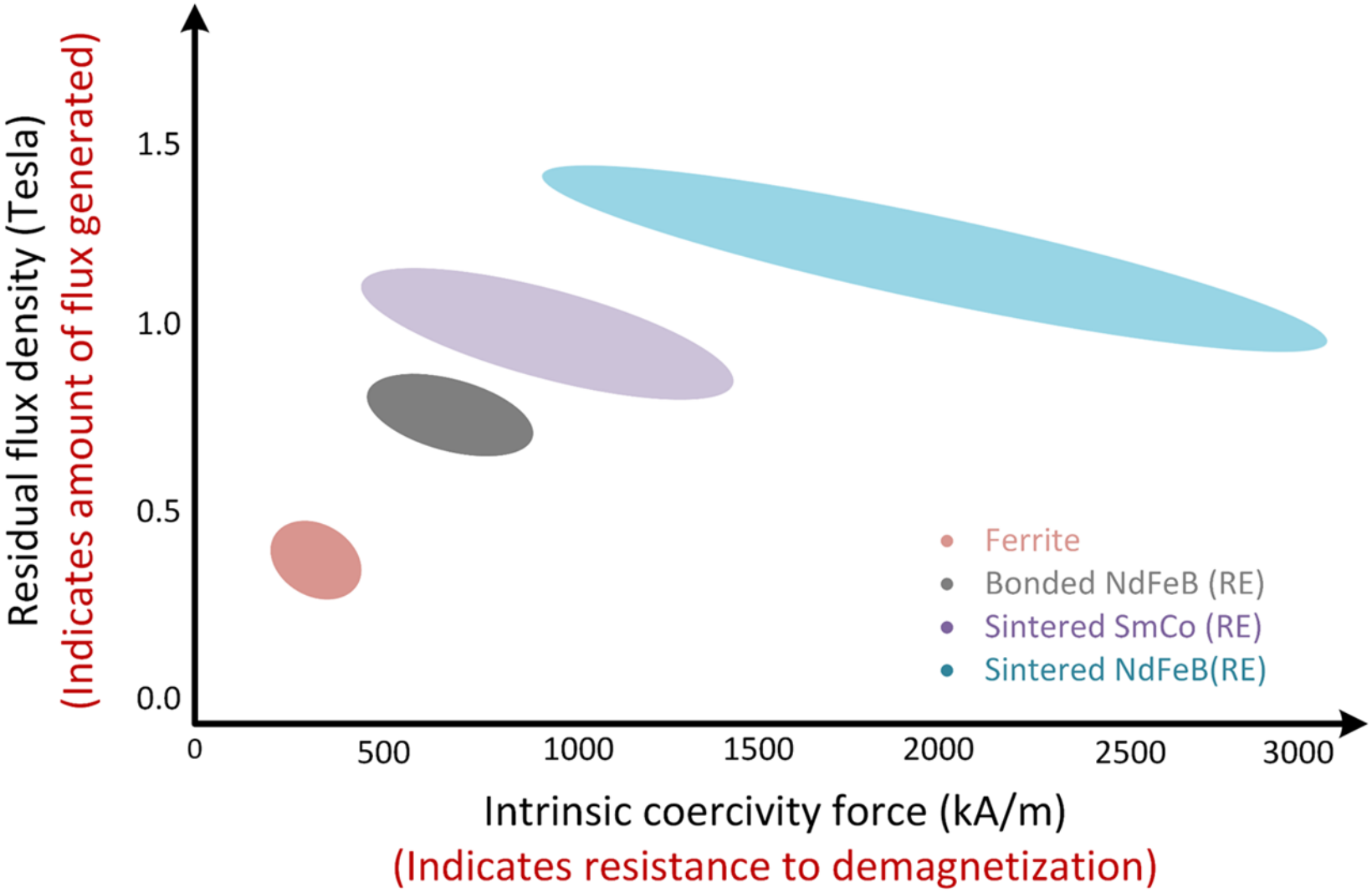
# Specification of electric motor powertrain for two-wheeler

**Emmo electric scooter**

[**Existing motor:** Sintered rare earth permanent magnet motor]

| Specification of vehicle drive | | | |
|---|---|---|---|
| **S.N** | Name | Unit | Value |
| **1** | Maximum vehicle mass including load | kg | 130 |
| **2** | Maximum (Rated) vehicle speed | kmph | 30 |
| **3** | Time to reach rated speed of vehicle | s | 15 |
| **4** | Rated speed of motor | rpm | 330 |
| **5** | Rated power of motor | W | 700 |
| **6** | Rated torque | Nm | 20 |
| **7** | Rated voltage | V | 48 |

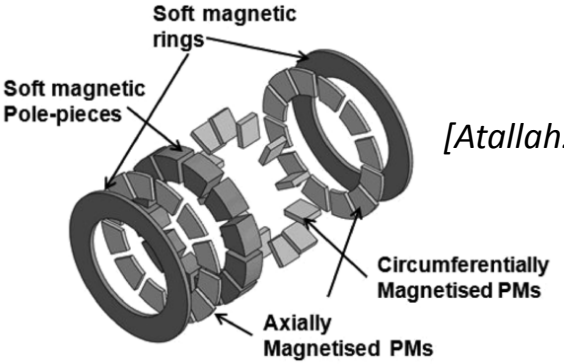
# Challenges in substituting rare earth magnet with ferrite in electrical machines



# Challenges in substituting rare earth magnet with ferrite in electrical machines

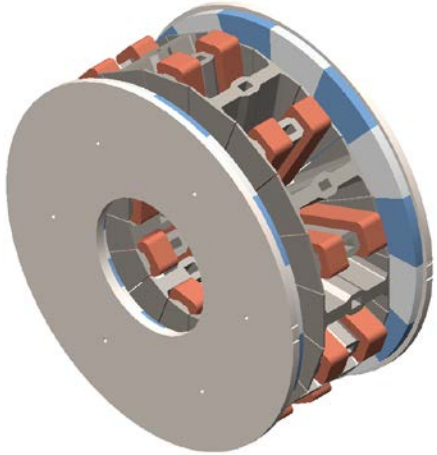
- What others are doing
  - Motor without any magnets
    - Switched reluctance motors
    - Synchronous reluctance motors


  - Motor with magnets
    - New topologies to that allows putting more magnet in an efficient way such as axial flux machines, dual rotor machines




*[Atallah2012]*

- Nanopyme motor topology and configuration offers
  - Low cost position sensing and simple controller
  - Easy to wound and easy to repair modular concentrated winding
  - Direct drive with no gears offers lesser components and improved reliability



Nanopyme motor topology

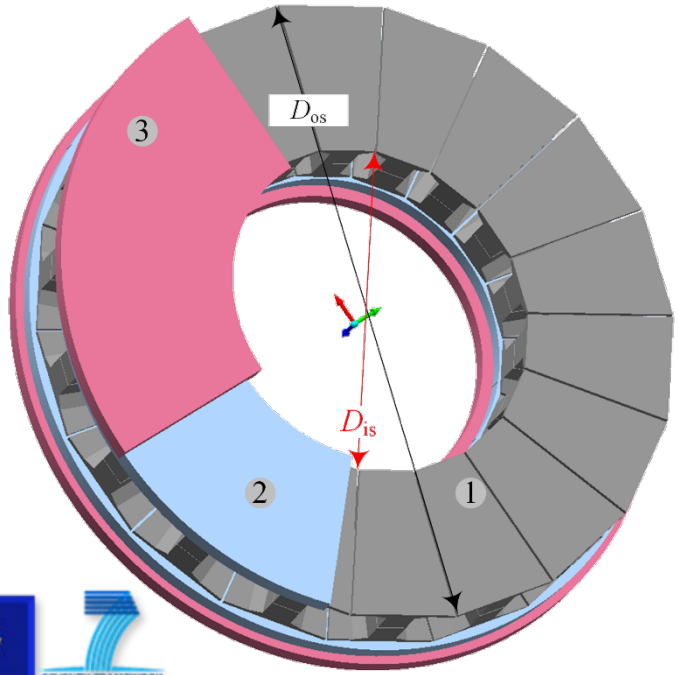
# Design details

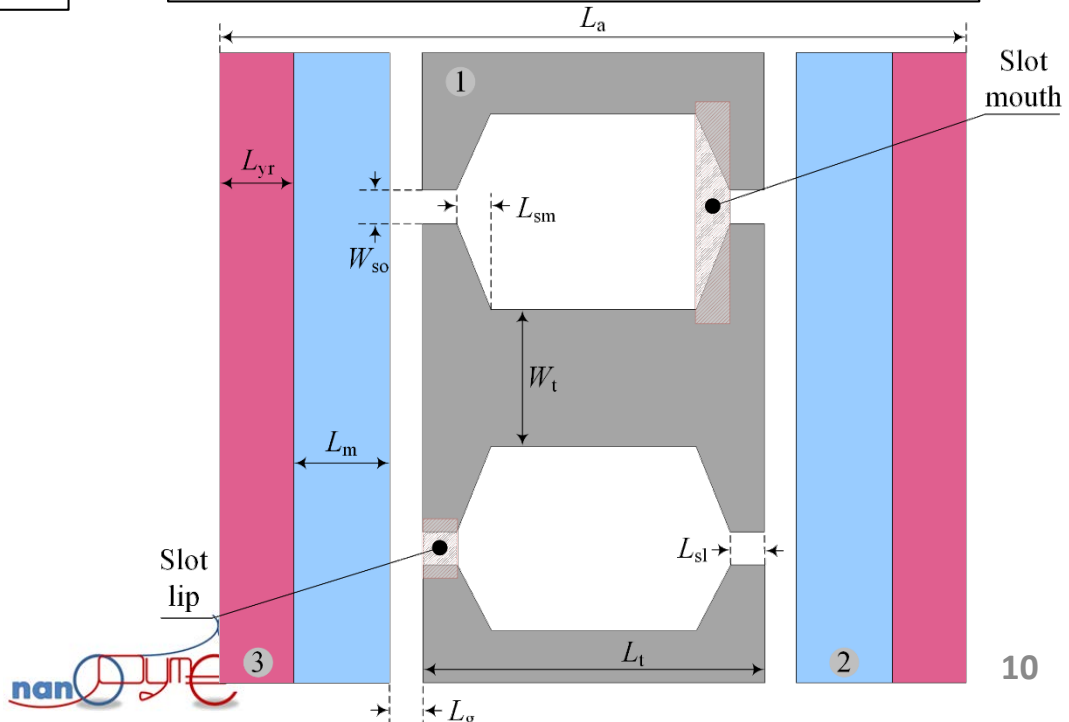
**Design constraints**

| | |
|---|---|
| Number of stator slots | 18 |
| Number of rotor poles | 16 |
| Length of airgap | 0.4 mm |
| Outer diameter of stator | 260 mm |
| Gross slot fill factor | 50% |
| Width of slot opening | 1 mm |
| Depth of slot lip | 2 mm |
| Depth of slot mouth | 2 mm |
| Current density of coil | 4.5 A mm$^{-2}$ |
| Ratio of pole arc to pole pitch | 1 |

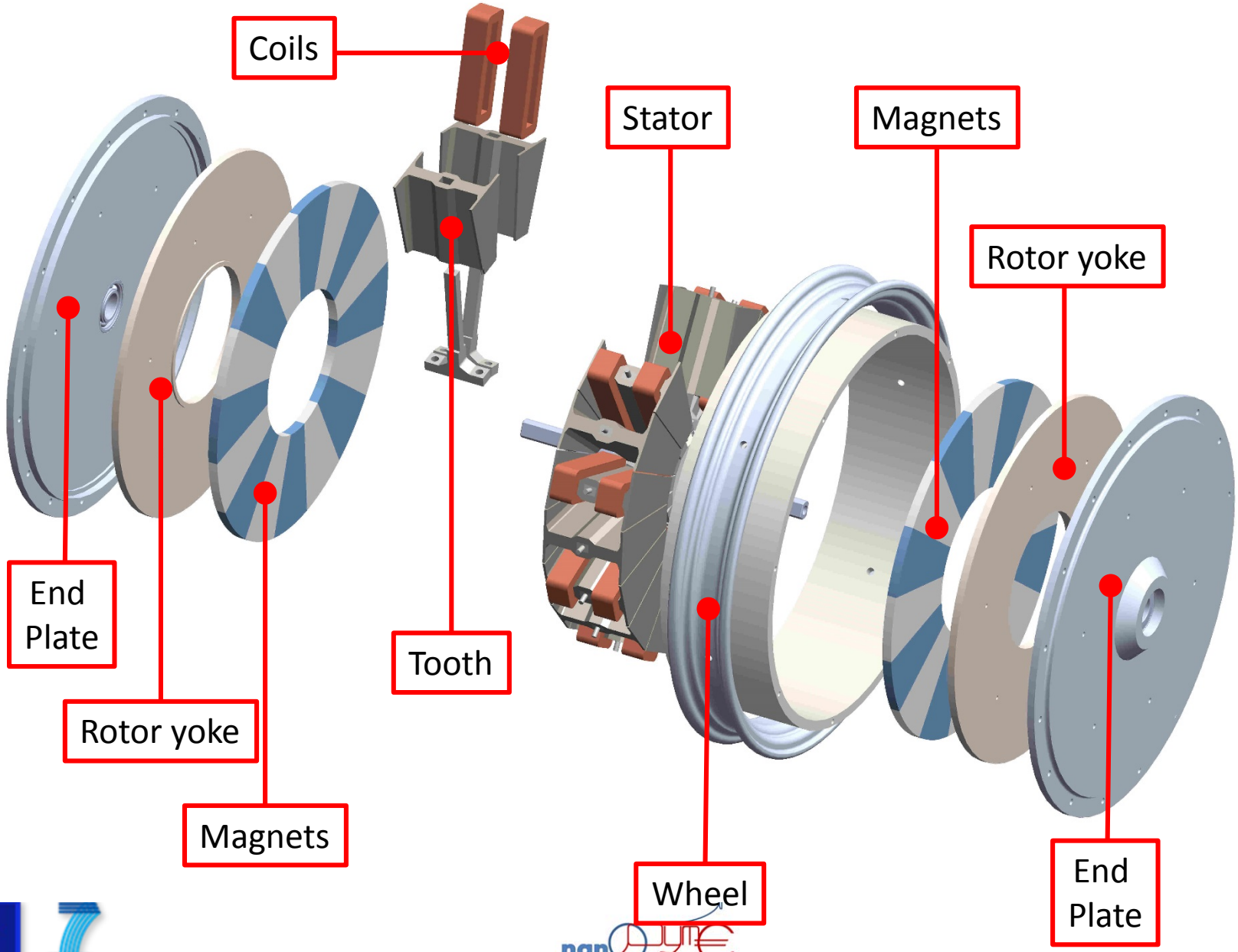
**Optimised designs**

| Design | 63 | 88 | 124 | 143 | 158 | 270 |
|---|---|---|---|---|---|---|
| $L_m$ (mm) | 7.5 | 9.5 | 8 | 7 | 7 | 7.5 |
| $h$ (%) | 0 | 10 | 5 | 0 | 5 | 10 |
| $\lambda_d$ (%) | 50 | 52.5 | 50 | 47.5 | 45 | 47.5 |
| $L_{yr}$ (mm) | 7 | 7 | 7 | 8 | 8 | 8 |
| $W_t$ (mm) | 11.3 | 11.9 | 11.3 | 10.8 | 10.2 | 10.8 |
| $N_c$ | 24 | 24 | 24 | 28 | 22 | 22 |
| $D_{ct}$ (mm) | 2.8 | 2.8 | 2.8 | 2.6 | 2.8 | 2.9 |
| $L_t$ (mm) | 32.4 | 30.6 | 32.2 | 32.6 | 33.4 | 32.6 |
| $L_a$ (mm) | 62.2 | 64.4 | 63 | 63.4 | 63.9 | 64.4 |
| $R_{ph}$ (mΩ) | 36 | 35 | 36 | 52 | 34 | 32 |
| $I_{ph}$ (A) | 28.0 | 28.4 | 28.2 | 23.4 | 28.5 | 29.4 |
| $P_{cu}$ (W) | 56.8 | 56.1 | 57.2 | 56.3 | 55.2 | 55.8 |

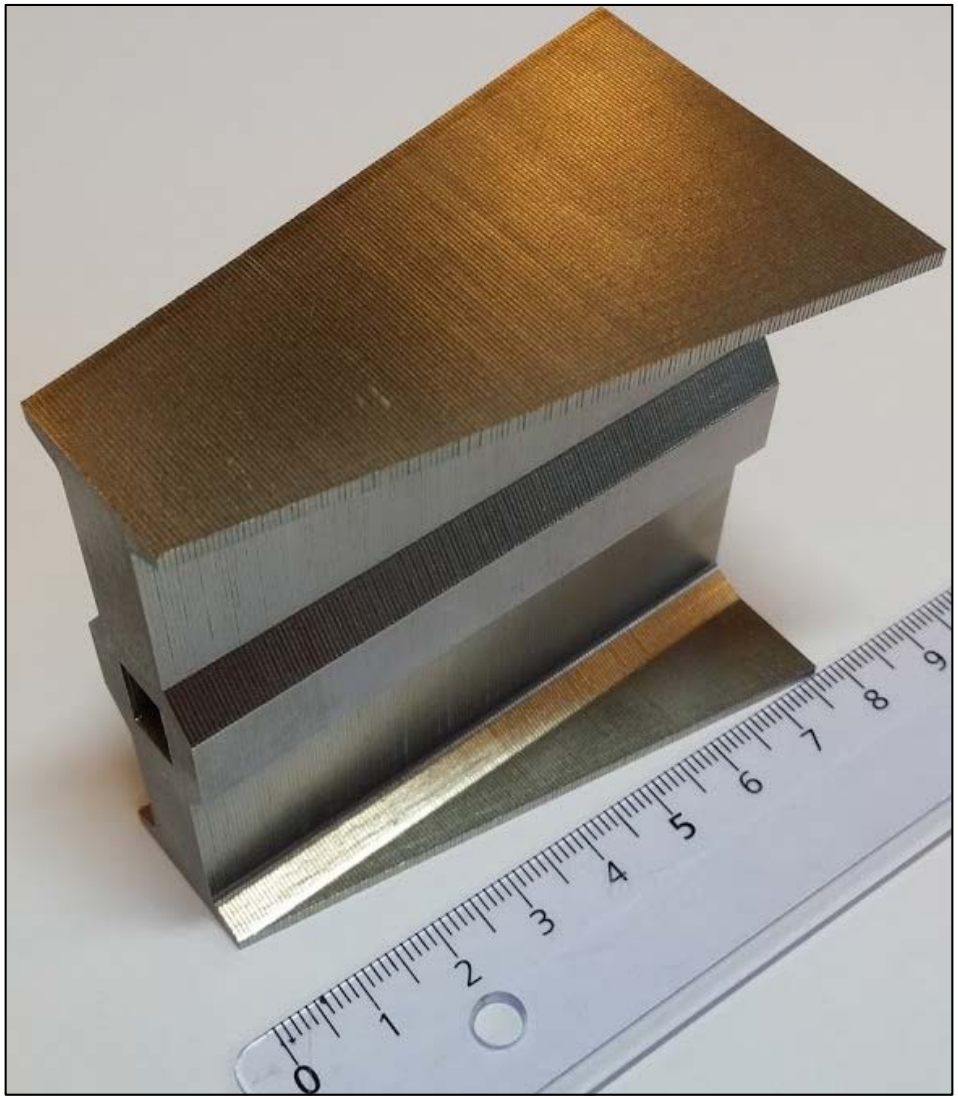


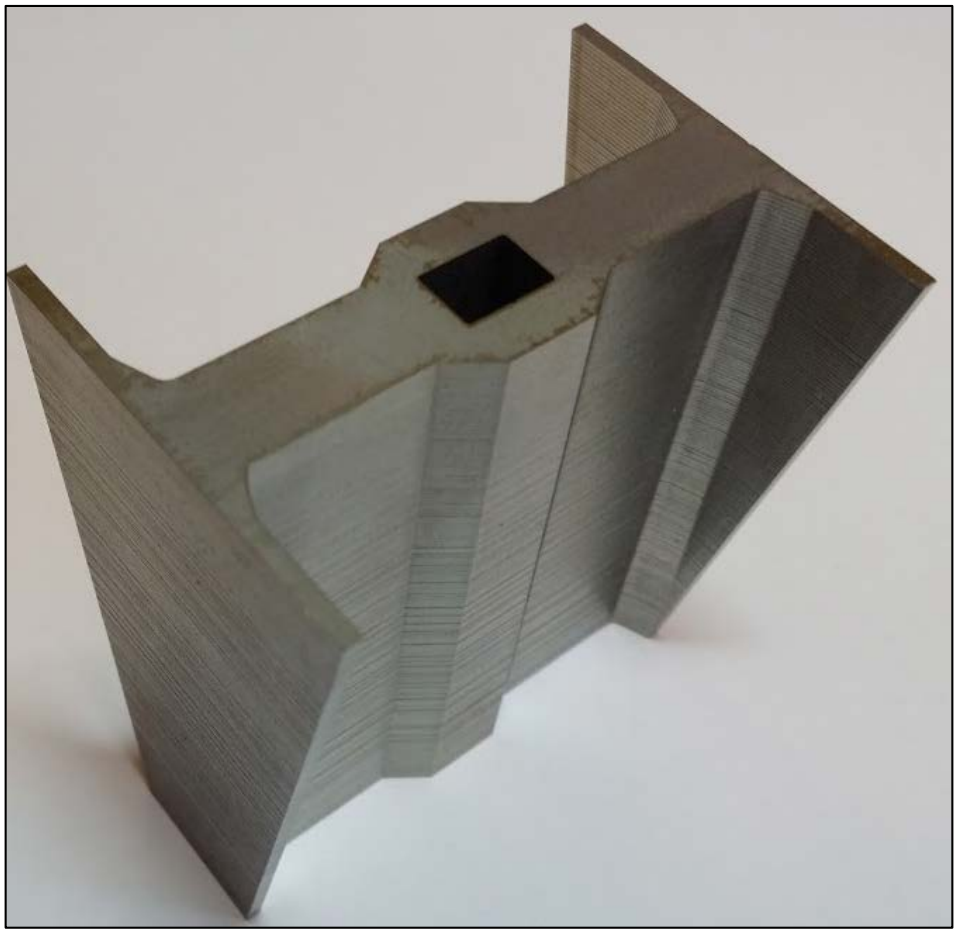



# Mechanical assembly of the motor



# Fabrication of motor - stator tooth



Material : M400-50A

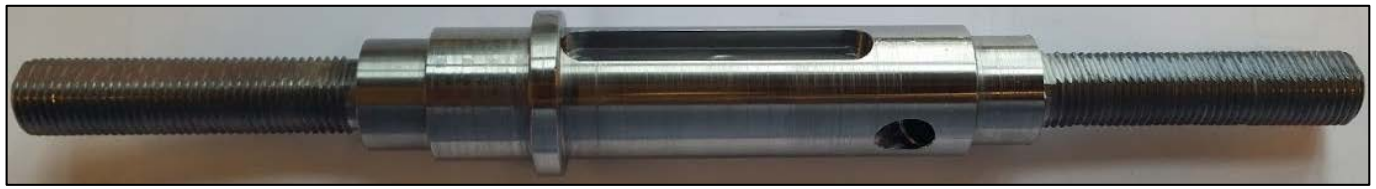
# Fabrication of motor - stator coils

# Fabrication of motor – tooth mounting assembly

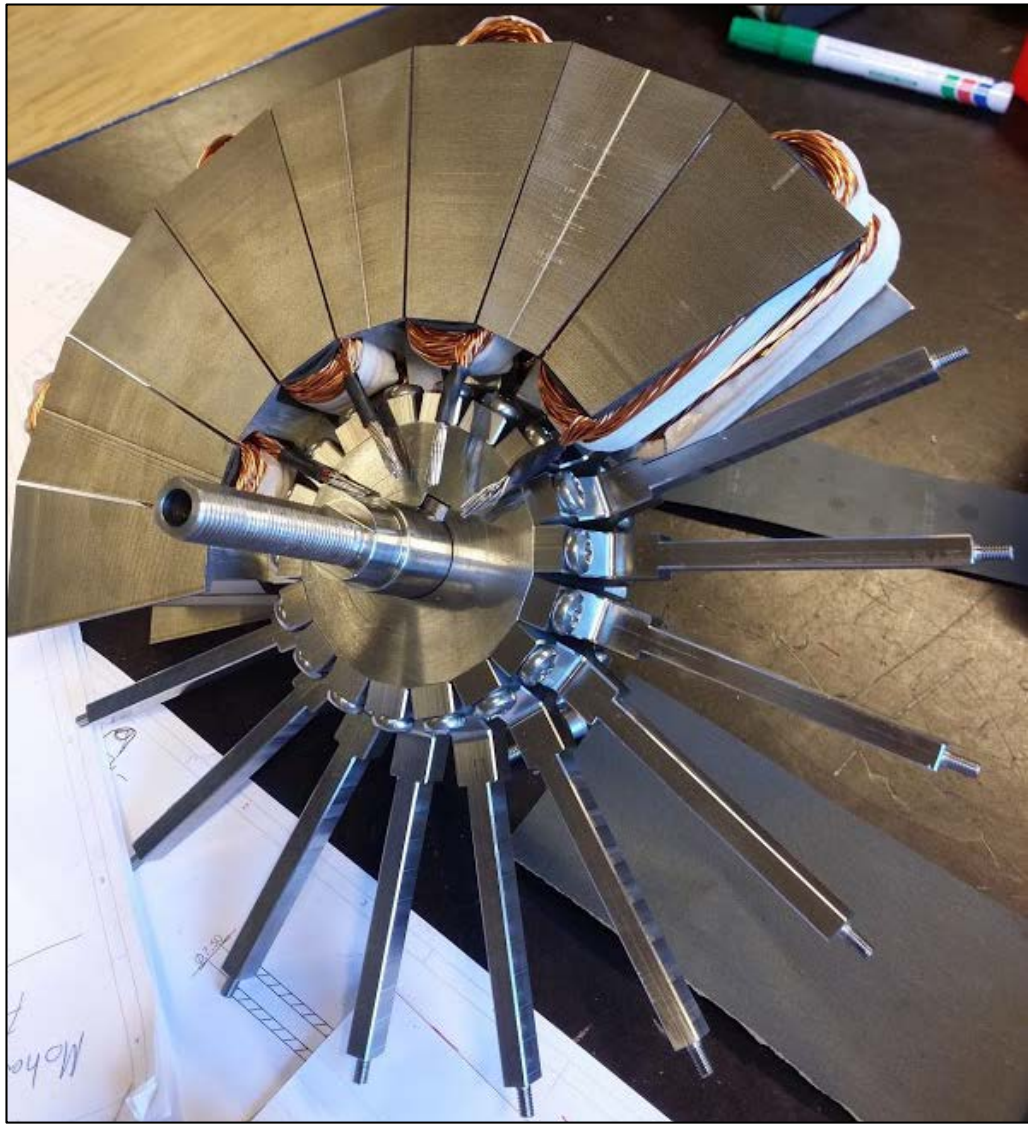
**Tooth holder**

**Tooth holder**

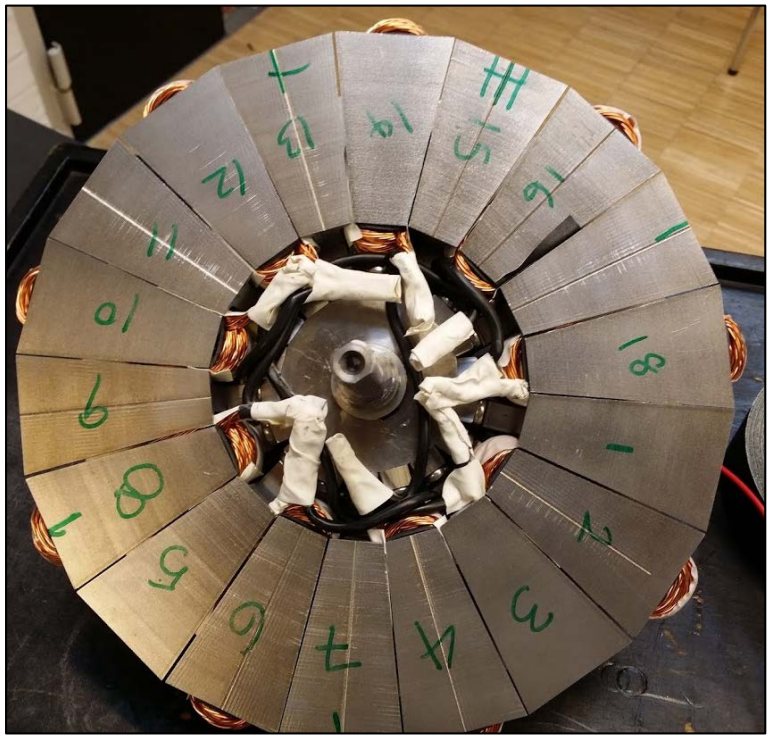
**Shaft**

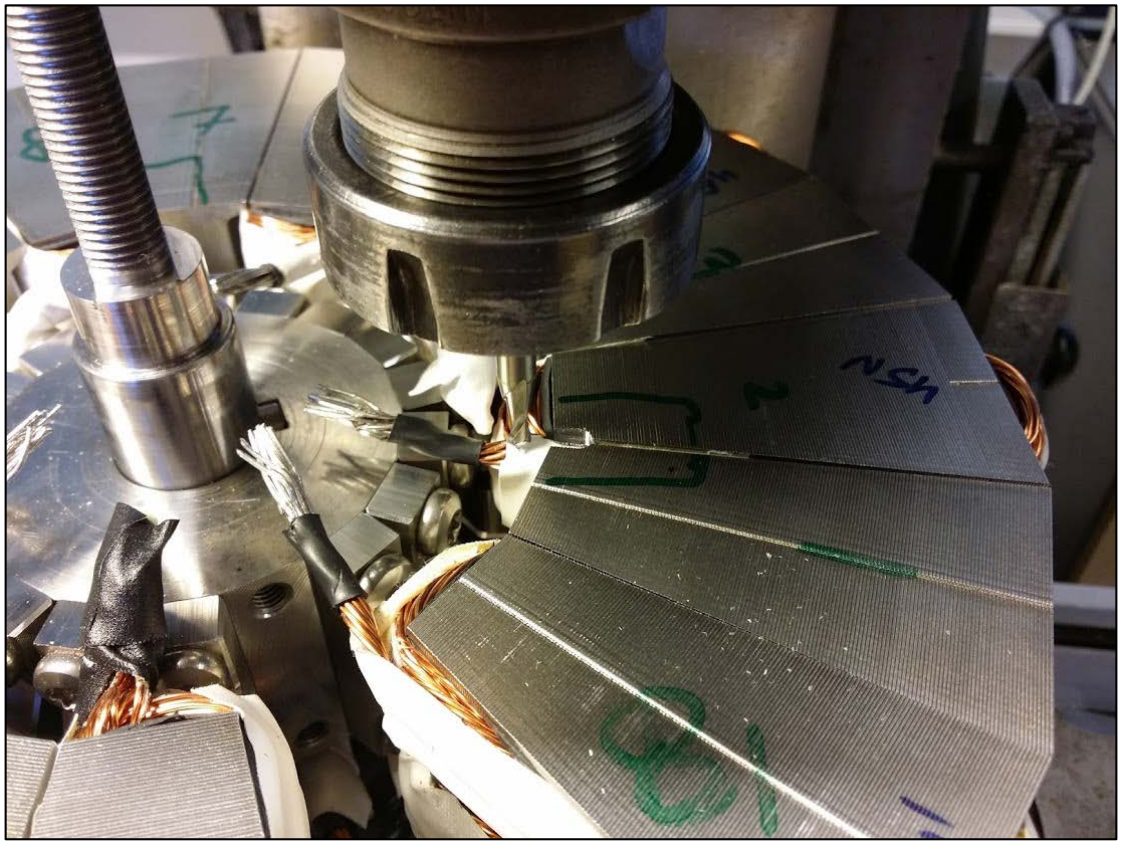


# Fabrication of motor – tooth mounting assembly

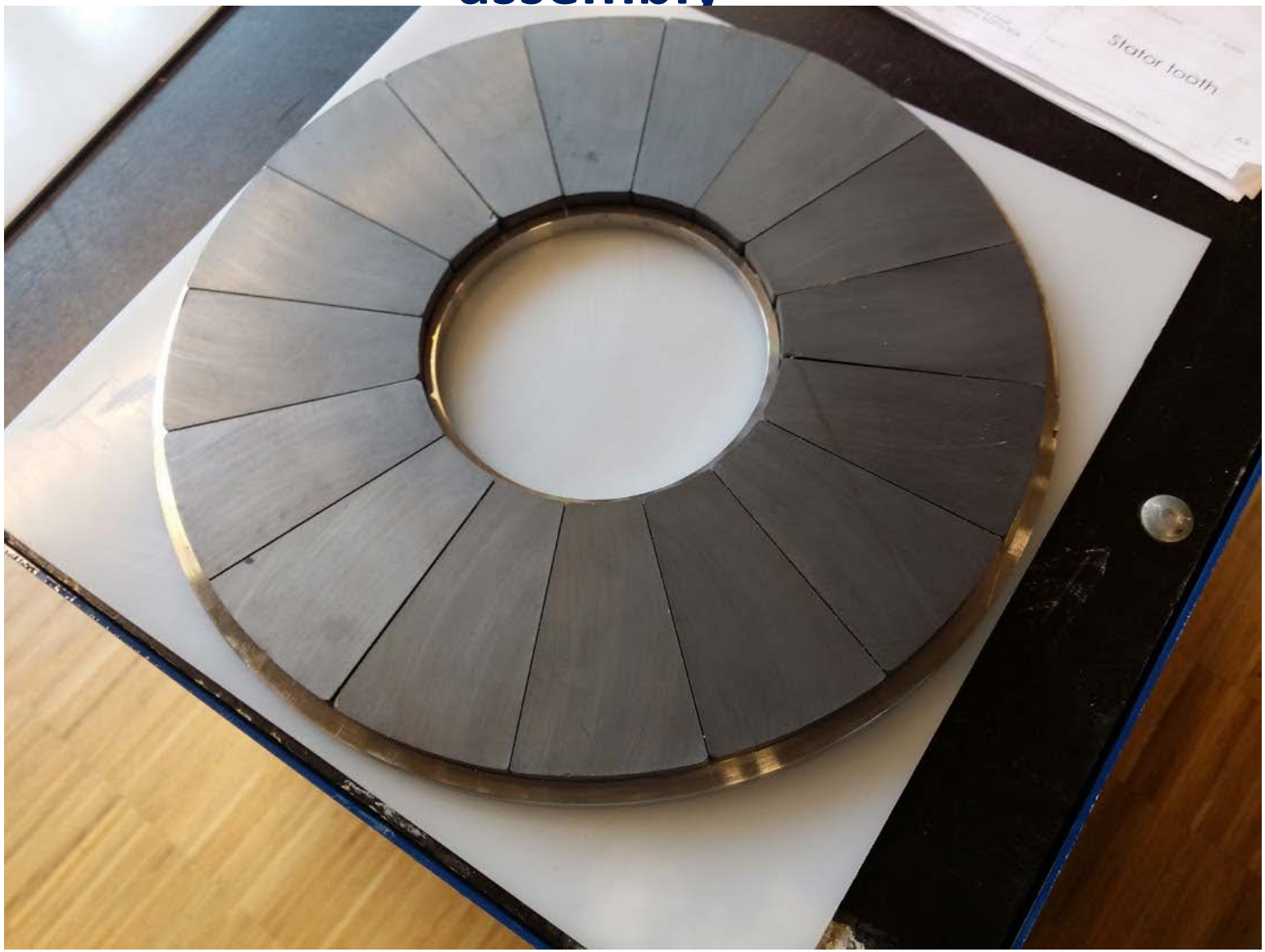


# Fabrication of motor – Completed stator and rotor position sensor mounting





# Fabrication of motor – Rotor yoke and magnet assembly



# Completed motor on vehicle

# Conclusion

- Introduction of improved energy density ferrite magnet based PM motors could improve the adoption rate of electric vehicles by offering low-cost powertrain

- DTU along with Nanopyme partners has fabricated and successfully completed first trial assembly of axial flux ferrite magnet motor for electric two-wheeler application

- In coming weeks DTU will fine-tune the motor assembly and integrate the motor to wheels of vehicle

- The on-board vehicle test of powertrain according to ISO 13064 standard is scheduled for October 2015. This will be followed by test bench evaluation of motor

## Contact


**Nenad Mijatovic**
Postdoc
DTU Electrical Engineering
Phone +45 45 25 35 07
nm@elektro.dtu.dk

**Muhammed Fasil**
PhD student
DTU Electrical Engineering
Phone +45-45-25-36-51
mfasil@elektro.dtu.dk


## Consortium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www.nanopyme-project.eu